TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 795

EFFECT OF SEVERAL SUPERCHARGER CONTROL METHODS

ON ENGINE PERFORMANCE

By Eugene W. Wasielewski and J. Austin King
Langley Memorial Aeronautical Laboratory

Washington
February 1941

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE NO. 795

EFFECT OF SEVERAL SUPERCHARGER CONTROL METHODS

ON ENGINE PERFORMANCE

By Eugene W. Wasielewski and J. Austin King

SUMMARY

The following superchargers, all applied to the same
hypothetical engine, have been compared analytically: a
single-speed, a two-speed, and a variable-speed DVL cen-
trifugal supercharger; the Szydlowski-Planiol supercharger
with both a single-speed and a two-speed transmission;
and a turbosupercharger. A constant manifold pressure was
maintained to the critical altitude.

From the calculations that were made, it is concluded
that the variable-speed DVL supercharger, the Szydlowski-
Planiol supercharger (with a two-speed transmission), and
the turbosupercharger (furnished with exhaust gas at 1500°
F and having an efficiency of 50 percent) give larger pro-
peller powers below the critical altitude than either the
single-speed or the two-speed DVL supercharger. For all
cases the increase in power over that obtained with the
two-speed DVL centrifugal supercharger is partly offset by
the power loss due to the additional weight. This weight
increase is small for the variable-speed and the
Szydlowski-Planiol superchargers; in the case of the tur-
bosupercharger, it is an appreciable disadvantage. In the
case of the variable-speed DVL supercharger, the exact
amount of gain in power also depends on the power required
for the dissipation of waste heat in the oil cooler. When
these various systems of supercharging are applied for a
condition of constant charge weight, which gives approxi-
mately constant engine stress up to the critical altitude,
their relative merits also depend on the power loss due to
the intercoolers required.

If all the losses mentioned are neglected, a large
increase in propeller power over the power given by the
two-speed DVL supercharger (in the vicinity of the gear-
shift point) can be realized with the turbosupercharger
(which showed the largest gain), the variable-speed DVL
supercharger, and the Szydlowski-Planiol supercharger.

INTRODUCTION

If a given engine is equipped with various single-speed superchargers, the power delivered to the propeller at any altitude below the critical will decrease as the critical altitude of the supercharger increases. This statement is true because the temperature rise in a single-speed supercharger is nearly constant at all altitudes. The constant temperature rise results in a large decrease in propeller power near the ground, owing to the decreased charge weight at a given manifold pressure and to the knocking limitations caused by the high engine inlet temperature as well as to the relatively large amount of power required by the supercharger. Since the temperature rise increases with the critical altitude of the supercharger, a drop in propeller power below the critical altitude will accompany an increase in the critical altitude.

On present-day engines, the two-speed supercharger and the turbosupercharger are used to improve this situation. Two new means have recently been advanced: the Szydlowski-Planiol supercharger (reference 1) and the planetary variable-speed transmission.

In this report, an analytical comparison of all these means has been made, under various operating conditions, for superchargers capable of maintaining sea-level pressure to approximately 25,000 feet. A description of the new means of supercharging is included.

DESCRIPTION OF UNITS CONSIDERED

The following combinations were considered in this report: a DVL centrifugal supercharger with a single-speed, a two-speed, a variable-speed, and a turbine drive; and a Szydlowski-Planiol supercharger with a single-speed and a two-speed drive.

The single-speed and the two-speed superchargers and the turbosupercharger were assumed to be the conventional types in use at present. Control in the first two types is obtained by throttling the inlet and, in the third type, by means of a waste gate in the engine-exhaust pipe.

The use of epicyclic gearing to obtain a variable-speed transmission is possible with a number of different arrangements; all these arrangements, however, are the same in principle and give the same theoretical efficiency.

In order to illustrate the principles involved, a simplified diagram of a drive proposed by Szekely is shown in figure 1. This planetary gear system consists of the spider A that is integral with the drive shaft; pinion B; gear D, which floats on the drive shaft; and the internal gear K, to which the supercharger rotor is attached. Gear F is integral with gear D and together with pinion G forms an oil pump that serves to load gear D. The overrunning clutch E is not essential but is merely a detail of this design; it serves to prevent the supercharger rotor from turning at a lower speed than the drive shaft.

The speed of the drive shaft A is the same as the low speed of an ordinary two-speed supercharger. If there is no resistance to the motion of D, it will rotate at a high speed and K will be at rest. By means of the oil pump, a load can be placed on gear D, causing it to slow down. As a result of the decrease in speed of D, the gear K is made to rotate faster, the speed of A being constant. When D is stationary, K attains its maximum speed. In practice, however, there is leakage in the pump and D cannot be completely stopped. The maximum attainable supercharger speed with a given set of gear will, therefore, be somewhat lower than the maximum speed. For the general case, the speed is variable down to zero; on account of the clutch, the minimum speed is the same as the speed of the drive shaft. It is evident that, in general, any intermediate speed can be obtained with a planetary gear system by controlling the speed of one of the gears.

The efficiency of the variable-speed drive is determined by the power required to hold the center gear D at a speed that will give the desired overdrive. The power supplied to the shaft A goes to the supercharger and to the shaft D from which the oil pump is driven. If Q and N are used to denote torque and speed, respectively,

$$Q_A N_A = Q_K N_K + Q_D N_D$$

where the subscripts refer to the components of the transmission (fig. 1). Also, from the equilibrium condition for pinion B,

$$Q_A = Q_K + Q_D$$

These two equations are combined to obtain an expression
for the power P required by the shaft D:

$$P_D = \frac{N_D}{N_K} \frac{N_K - N_A}{N_A - N_D} P_K$$

The factor $\dfrac{N_K - N_A}{N_A - N_D}$ is the train ratio M, which is con-
stant for a given set of gears. Substitute

$$\frac{P_D}{P_K} = \frac{N_A + MN_A - N_K}{N_K}$$

The quantity $N_A + MN_A = N_{K_{max}}$, the maximum speed of K,
which is reached when $N_D = 0$. Thus, the losses as a
fraction of the supercharger power are

$$\frac{P_D}{P_K} = \frac{N_{K_{max}} - N_K}{N_K} \tag{1}$$

For a given set of gears and shaft speed, the efficiency
of the drive is a function only of the supercharger speed.
If there were no slippage, $N_{K_{max}}$ would be the maximum
supercharger speed. With the transmission shown in figure
1, however, the shaft D cannot be brought to rest, and it
is necessary to make $N_{K_{max}}$ slightly higher than the
highest supercharger speed; the effect of this condition
is to lower somewhat the efficiency of the drive.

For the calculations in this paper, the single-speed,
the two-speed, and the variable-speed drives were applied
to the DVL supercharger described in reference 2. This
supercharger is of the centrifugal type, having a fully
shrouded impeller and inlet vanes mounted on a separate
wheel keyed to the impeller. The characteristics of this
supercharger are shown in figure 2 (from reference 2),
which gives H_{ad} and η_{ad} as a function of V_1 for sev-
eral speeds where

H_{ad} adiabatic work required to compress 1 pound of
        air in foot-pounds per pound given by

$$H_{ad} = \frac{\gamma}{\gamma - 1} RT_i \left[\left(\frac{p_o}{p_i} \right)^{\frac{\gamma-1}{\gamma}} - 1 \right] \qquad (2)$$

γ ratio of specific heats (c_p/c_v)

c_p specific heat of air at constant pressure,
        Btu per pound per degree Fahrenheit

c_v specific heat of air at constant volume,
        Btu per pound per degree Fahrenheit

R gas constant

T_i temperature of the air entering the supercharger,
        degrees absolute

p_i absolute pressure of air entering supercharger,
        pounds per square foot

p_o absolute pressure of air leaving supercharger,
        pounds per square foot

V_i inlet volume, cubic feet per second

η_{ad} adiabatic efficiency based on temperatures given

        by $\eta_{ad} = \dfrac{\text{adiabatic temperature rise}}{\text{actual temperature rise}}$ (also

        defined by equation (4))

The Szydlowski-Planiol supercharger (reference 1),
to which both single-speed and two-speed drives were ap-
plied, is a combination of several axial-flow wheels with
a centrifugal impeller. A cross section of this super-
charger is shown in figure 3. The centrifugal impeller
is indicated by P; R_1, R_2, and R_3 are axial-flow
wheels keyed to the same shaft. Two entrances, E_p and
E_s, contain guide vanes, the angles of which are adjust-
able. Near the critical altitude, the air enters at E_p.
The position of the guide vanes is such as to make $\beta < 0$
(where β is the angle of attack of the blades of wheel
R_1); R_1 then acts as a compressor. As the required pres-
sure ratio becomes smaller (below the critical altitude),
the guide vanes in E_p are so operated that the blades of
R_1 are made to act first as neutral blades ($\beta = 0$) and
finally as turbine blades ($\beta > 0$). In this last case,

some of the energy normally lost in throttling is used to
help drive the supercharger. For very low pressure ra-
tios, the air enters at E_s, where it can be given the
proper whirl for shockless entrance into P.

The characteristics of this supercharger are shown in
figure 4. In this case the adiabatic efficiency is given
as a function of the adiabatic temperature rise for vari-
ous tip speeds for a condition of constant outlet pressure
and constant weight of air pumped (reference 3). The
adiabatic temperature rise is defined by

$$\Delta T = T_i \left[\left(\frac{p_o}{p_i} \right)^{\frac{\gamma-1}{\gamma}} - 1 \right] \qquad (2a)$$

METHODS

The atmospheric data given in reference 4 were used to
make calculations for two manifold pressures: 29.92 and
40 inches of mercury absolute. For each of these pressures,
two cases were considered: (1) supercharger without inter-
cooling, and (2) supercharger with sufficient intercooling
to give constant charge weight from the sea level to the
critical altitude. The first case corresponds to a con-
ventional supercharger installation, and the second imposes
approximately constant stress upon the engine to the crit-
ical altitude. For the case of constant charge weight
(case 2), cooling was assumed to be sufficient above the
critical altitude to lower the engine inlet temperature
by the same fraction of the total thermal head (difference
between supercharger outlet and atmospheric temperature)
as at the critical altitude. For the two-speed supercharger,
the transition curve from the low-speed critical altitude
to the point at which the gear change is made (see figs. 8
and 14, to be discussed later) was obtained by assuming
that the engine inlet temperature was lowered by 40 percent
of the thermal head; large deviations from this value
change the curve very little.

Supercharger Calculations

Each method of supercharging was applied to the same
hypothetical engine, the displacement of which was obtained

by a method described later. The manifold temperature,
the back pressure (for the turbosupercharger), and the
power required by the supercharger were calculated; for
the cooled condition, the amount of intercooling required
was obtained from the temperature drop and the specific
heat of air. Inasmuch as these supercharger character-
istics are based on temperature measurements, the super-
charger power obtained from figure 2 was divided by 0.95
to account for losses not appearing in the temperature.
The efficiency of the low-speed gears was taken as 90
percent; that of the high-speed gears was taken as 85
percent.

Single-speed DVL supercharger.- The single-speed
supercharger was assumed to be driven at 26,700 rpm. In
order to determine the critical altitude, the supercharger
was assumed to operate at maximum efficiency at this
speed. The critical altitude, then, is the one where the
value of H_{ad} from equation (2) is the same as that picked
from the curve. The complete supercharger conditions were
obtained from the following equations:

$$\frac{T_{o_{ad}}}{T_i} = \left(\frac{p_o}{p_i}\right)^{\frac{\gamma-1}{\gamma}} \tag{3}$$

$$\frac{T_{o_{ad}} - T_i}{T_o - T_i} = \eta_{ad} \tag{4}$$

$$pv = WRT \tag{5}$$

where $T_{o_{ad}}$ adiabatic exit temperature, degrees absolute

T_o actual exit temperature, degrees absolute

p pressure, pounds per square foot absolute

v volume, cubic feet

W weight, pounds

T temperature, degrees absolute

The displacement of the engine can be found from the
equation (from reference 5, changed to American notation):

$$v_i = v_E \left[1 + \frac{1 - \dfrac{p_e}{p_0}}{\gamma(r - 1)} \right] \qquad (6)$$

where v_i volume of the charge entering engine, cubic
feet per second

v_E displacement of engine, cubic feet per second

r   compression ratio

p_e exhaust back pressure, pounds per square foot
absolute

A value of $\gamma(r - 1)$ equal to 7.7 was assumed. The value
of the engine displacement, found from the conditions at
the critical altitude for sea-level manifold pressure and
equation (6), was used in all subsequent calculations.

By means of equations (2), (3), (4), (5), and (6),
calculations can be made for the conditions below and
above the critical altitude for all cases considered.
Below the critical altitude, the supercharger is throttled
at the inlet; above the critical altitude, there is no
throttling, but the speed is held at 26,700 rpm.

Two-speed DVL supercharger.- The two-speed super-
charger was assumed to have speeds of 15,000 and 26,700
rpm. Since performance at the high speed can be obtained
from the single-speed case, calculations need be made only
for the low speed. Above the first critical altitude, the
supercharger is held at 15,000 rpm until the gear-shift
point is reached. Calculations are made in the same way
as for the single-speed supercharger.

Turbosupercharger.- At all altitudes, the efficiency
of the turbine was assumed to be 50 percent with an ex-
haust temperature of 1500° F. The maximum allowable speed
was taken as 26,700 rpm, and the calculations at and above
the critical altitude were made for this speed.

In order to find the engine back pressure and the
supercharger operating point, the condition that must be
satisfied is the equality of the supercharger power and
the turbine output. The total power required by the super-
charger is

$$P_s = \frac{W_a \; H_{ad}}{0.95 \; \eta_{ad}}$$

where P_s total supercharger power, foot-pounds per second

       W_a weight of air flowing, pounds per second

     0.95   factor to account for work not appearing as rise in temperature

This value of P_s must be equal at all times to the power P_t expended by the turbine,

$$P_t = W_e \; c_p (1960 - T_{e_{ad}}) 778 \times 0.5$$

where the temperature at the end of an adiabatic expansion. $T_{e_{ad}}$ is given by

$$\frac{T_{e_{ad}}}{T_e} = \left(\frac{p_i}{p_e}\right)^{\frac{\gamma-1}{\gamma}}$$

     P_t total turbine power, foot-pounds per second

     W_e weight of exhaust gas, pounds per second

The value 778 is the mechanical equivalent of heat, foot-pounds per Btu.

    The weight of the exhaust gas is found by the use of the equations for short tubes as given in reference 6. The values of c_p and R for the exhaust gas are 0.289 and 53.81, respectively, in accordance with data given in reference 7; these data are based on the assumption that the exhaust gas consists of 13 percent CO_2, 14 percent H_2O, and 73 percent N_2 by weight. If P_t is set equal to P_s and the resulting equation is combined with equations (2), (3), (4), (5), and (6), a solution can be obtained for all altitudes for the turbosupercharger.

    Variable-speed DVL supercharger.- The power loss for the supercharger with the variable-speed drive was calculated from figure 2 and equation (1) on the assumption that a slippage of 4 percent was present. Figure 5 gives the losses for the various conditions for a drive infinitely variable from 0 to full speed (26,700 rpm). The losses

for the drive with overrunning clutch occur at speeds be-
tween 15,000 and 26,700 rpm. The supercharger operating
points can be found at all altitudes by the use of the
curves in figure 2 and equations (2), (3), (4), (5), and
(6). As with the turbosupercharger, there is no throt-
tling, and the speed is limited to 26,700 rpm.

    Szydlowski-Planiol supercharger.- Because the charac-
teristic curves of the Szydlowski-Planiol supercharger are
given only for the condition of constant charge weight,
calculations were made only for this condition; no calcu-
lations were made above the critical altitude for this su-
percharger. Figure 6 (from reference 1) shows the alti-
tude to which sea-level pressure can be maintained with
the DVL, the Szydlowski-Planiol, and the ideal radial-
blade superchargers. The operating speed of the Szydlowski-
Planiol supercharger was chosen from this curve to give
the same critical altitude as the DVL supercharger. By
means of figures 5 and 6 and equations (2a) to (6), calcu-
lations can be made as before for both the single-speed
and the two-speed drives.

Engine and Power Calculations

    No account was taken of the effect of the evapora-
tion of the fuel. The gross engine horsepower was assumed
to be proportional to the weight of air inducted; a fac-
tor of 550 horsepower per pound of air per second at sea
level was used. The propeller power is the difference be-
tween the gross engine power and the power required for
the supercharger. No allowance was made for the power re-
quired by intercoolers or oil coolers (variable-speed
drive). Correction for the increase in charge due to
decreased back pressure was made by means of equation (6).
The increased power due to the work done by the super-
charger on the intake stroke and the decrease in back
pressure was taken as

$$\Delta P = \frac{\Delta p \ v_E}{550}$$

where ΔP is the gain in horsepower and Δp is the dif-
ference between the intake and the exhaust pressures,
pounds per square foot. Although this method does not
give an exact value for the propeller power, it is suf-
ficiently accurate for purposes of comparison.

    In order to find the relative fuel condumptions of

the cases considered, an over-all efficiency factor was
obtained. This factor is the ratio of the propeller power
to the gross engine power.

RESULTS AND DISCUSSION

The assumptions made in regard to the power gain due
to the change in pressure at the engine inlet and exhaust
are applied to the same extent for all gear-driven exam-
ples. These assumptions, however, have a different effect
on the turbosupercharger and, as a result, the relative
performance of this unit is somewhat better than will be
indicated because the gain in power due to lowering the
back pressure is less than the value assumed.

Sea-level manifold pressure to the critical altitude.-
The propeller power obtained with each method of super-
charging with no intercooling is shown in figure 7 for sea-
level manifold pressure. The unsuitability of the single-
speed supercharger is immediately obvious because of the
small power obtained at low altitudes. The possibilities
of the variable-speed drive are shown by the curve for the
ideal case.

The two-speed supercharger shows marked improvement
in propeller power, especially near the low-speed critical
altitude. Changing the gear ratio will give the low-speed
power peak at any desired altitude; the two parts of the
low-speed curve will be shifted to a new position but will
remain approximately parallel to the lines shown in the
figure. Thus, an increase in the low-speed critical alti-
tude can be obtained at the expense of the power near the
ground.

Regardless of the gear ratio chosen, the variable-
speed supercharger and the turbosupercharger show a con-
siderable advantage (as much as 20 percent at the gear-
shift point) over the two-speed supercharger. With an
overrunning clutch as in figure 1, however, there is an
advantage only above the low-speed critical altitude,
since the variable-speed drive is not used below 10,000
feet. A supercharger having a drive variable from zero
to full speed gives better low-altitude performance than
the two-speed supercharger and the turbosupercharger. The
propeller power for the variable-speed drive will be
lowered because of the power required to dissipate the

waste heat in an oil cooler. (See fig. 5.) The total
oil-cooling capacity required will be about twice that of
an engine with a two-speed supercharger. It is interest-
ing to note that, even if the power required because of
the additional cooling requirements were as great as the
power to be dissipated, the variable-speed drive would
still show a markedly higher propeller power than the two-
speed supercharger at certain altitudes.

The propeller power for the turbosupercharger and
the variable-speed supercharger is decreased by the power
required to carry the additional weight of these units;
the amount of extra weight will be about 200 pounds for
the turbosupercharger and about 10 pounds (not including
cooler) for the supercharger with a variable-speed drive.
The corrections due to this weight, however, will be small
compared with the gain in propeller power, and both these
superchargers can be expected to give a substantial in-
crease in power over the two-speed supercharger. This in-
crease is obtained, especially in the case of the turbo-
supercharger, at the expense of increased weight per
horsepower at some altitudes.

Figure 8 shows the propeller power for the condition
of constant charge weight below the critical altitude.
The beneficial effect of cooling the charge to constant
weight is especially noticeable for the single-speed DVL.
supercharger, but it is still considerably inferior to the
other methods of supercharging. Both the turbosupercharger
and the single-speed Szydlowski-Planiol supercharger ap-
proach constant propeller power below the critical altitude
although considerably more power is obtained with the tur-
bosupercharger; this superiority persists above the criti-
cal altitude, since the power curve above the critical
altitude for the Szydlowski-Planiol supercharger can be
considered to be approximately parallel to that of the DVL
supercharger. Between the first and the second critical
altitudes, the Szydlowski-Planiol supercharger produces
somewhat greater propeller power than the DVL variable-
speed supercharger. This greater power is due to the rel-
atively low efficiency of the DVL supercharger at high
speed. Slight corrections must again be made for addi-
tional weight; although no values are available, the extra
weight of the Szydlowski-Planiol supercharger is probably
about 30 pounds. There will be a slight increase in
weight per horsepower of the DVL variable-speed and the
Szydlowski-Planiol superchargers as compared with a two-
speed supercharger, but only near the critical altitudes.

The conclusions obtained from figure 8 must be modified to take into account the intercooling requirements shown in figure 9. The large amount of cooling required by the single-speed DVL supercharger, which is about twice that required by the single-speed Szydlowski-Planiol supercharger, considerably lowers the propeller power. As a result of the intercooling requirements, the advantage of the turbosupercharger is somewhat reduced. The general trend, however, will quite certainly be the same; the best results will be obtained with the two-speed Szydlowski-Planiol supercharger, the DVL variable-speed superchargers, and the turbosupercharger, with the turbosupercharger producing slightly more propeller power than the others. On the other hand, the practical disadvantages of the turbosupercharger will make it somewhat less desirable than the analysis indicates.

The manifold temperatures for the different superchargers are shown in figure 10. The high temperature shown by the single-speed and the two-speed DVL superchargers in the uncooled case will probably necessitate a reduction in the propeller power owing to the limitations imposed by knock. All gear-driven superchargers follow the same temperature curve for the constant charge-weight case except for the slight deviation made by both two-speed superchargers near the low-speed critical altitude.

The relative values of the fuel consumption as indicated by the over-all efficiency factor are illustrated in figure 11. The marked advantage of the turbosupercharger in this respect is immediately evident. Cooling is shown to have practically no effect because the curves for both the cooled and the uncooled conditions are either superposed or very close to each other. In fact, because of the horsepower required for cooling, the fuel consumption for the cooled cases will be higher.

The engine back pressure for the turbosupercharger is shown in figure 12. The pressure falls below 29.92 inches of mercury at about 5000 feet. The waste gate is fully closed at the critical altitude but must be opened again above the critical altitude in order to prevent the turbine from overspeeding.

Manifold pressure of 40 inches of mercury to the critical altitude.- Figure 13 shows the propeller power obtained without intercooling for a manifold pressure of 40 inches of mercury. As in the case of sea-level manifold

pressure, the advantage of the turbosupercharger and the
variable-speed supercharger is clearly shown. In this
case, however, the drive with an overrunning clutch is
shown to better advantage than with sea-level manifold
pressure because the low-speed critical altitude is near
the ground.

The propeller power for the case of 40 inches of mer-
cury manifold pressure and constant charge weight is shown
in figure 14. The curves show that the difference between
the variable-speed DVL supercharger and the two-speed
Szydlowski-Planiol supercharger is small, the variable-
speed supercharger again being at a disadvantage near the
critical altitude because of the low efficiency of the DVL
supercharger at high speeds.

If the intercooler requirements shown in figure 15
and the power due to additional weight as well as the power
required for dissipating the waste heat of the variable-
speed drive are taken into account, the two-speed Szydlowski-
Planiol supercharger probably produces greater power at all
altitudes than the DVL supercharger with the variable-speed
drive. The large amount of cooling required by the turbo-
supercharger will again bring the propeller-power curve
closer to the others.

The manifold temperatures are shown in figure 16.
The propeller power for both the single-speed and the two-
speed DVL superchargers will probably be lessened because
of the limitations imposed by combustion knock. Knock may
also limit the power for the variable-speed supercharger
and the turbosupercharger. It will be impossible to uti-
lize a manifold pressure of 40 inches of mercury without
cooling. As before, the manifold temperatures for all the
gear-driven superchargers with constant charge weight fall
on the same curve, with the exception of the two-speed
superchargers near the low-speed critical altitude.

Figure 17 illustrates the greater efficiency of the
turbosupercharger for the manifold pressure of 40 inches
of mercury. Of all the gear-driven superchargers consid-
ered, the Szydlowski-Planiol will probably give the least
fuel consumption over a wide range when all factors are
considered.

The engine back pressure for the higher manifold
pressure is shown in figure 18. The difference between
the manifold and the back pressures is somewhat smaller

near the critical altitude for a manifold pressure of 40
inches of mercury than it is for 29.92 inches of mercury.
The increased power available owing to the higher pressure
drop across the turbine is more than balanced by the in-
creased supercharger work that must be done.

CONCLUSIONS

For the supercharging conditions considered in this
report, an analytical study shows:

1. When the power required to dissipate the waste
heat was neglected, a DVL supercharger having a variable-
speed drive showed considerable improvement in performance
over a DVL two-speed supercharger. The increase in pro-
peller power can be as much as 20 percent in a favorable
case, the greatest improvement occurring at the gear-shift
point.

2. The Szydlowski-Planiol supercharger equipped with
a two-speed drive gave a calculated performance approxi-
mately the same as that of the DVL supercharger with a
variable-speed drive when it was assumed that any effects
due to increase in weight may be neglected.

3. An exhaust-gas turbine receiving gas at 1500° F
and having an efficiency of 50 percent showed better per-
formance at all altitudes than either the variable-speed
or the Szydlowski-Planiol supercharger with either single-
or two-speed drive when the effects due to the increase in
weight were neglected.

4. The exact amount of gain in propeller power over
the DVL two-speed supercharger will be determined by the
power required to dissipate (in an oil cooler) the waste
heat for the DVL variable-speed supercharger by the in-
crease in the weight of the installation for all super-
chargers and by the intercooler power for the conditions of
constant charge weight. The extra weight of the super-
charger and drive is negligible for the DVL variable-speed
and the Szydlowski-Planiol superchargers, but for the tur-
bosupercharger, it is an appreciable disadvantage.

Langley Memorial Aeronautical Laboratory,
        National Advisory Committee for Aeronautics,
            Langley Field, Va., August 12, 1940.

REFERENCES

1. Métral, Albert:　Le compresseur centrifuge Szydlowski-Planiol.　L'Aeronautique, 20 année, no. 235, Dec. 1938, Suppl.

2. von der Nüll, Werner:　The Design of Airplane-Engine Superchargers.　T.M. No. 839, NACA, 1937.

3. Salez, J.:　Notes sur les compresseurs d'aviation centrifuges.　Assoc. Tech. Maritime et Aéro., June 1939.

4. Brombacher, W. G.:　Altitude-Pressure Tables Based on the United States Standard Atmosphere.　Rep. No. 538, NACA, 1935.

5. Zeyns, J., and Caroselli, H.:　Bestimmung der Höhen-leistung von Flugmotoren auf Grund von Leistungs-messungen bei Bodenbedingungen.　Jahrb. 1938 der deutschen Luftfahrtforschung, pp. II 7-15.　R. Oldenbourg (München).

6. Eshbach, Ovid W.:　Handbook of Engineering Fundamentals. John Wiley & Sons, Inc., 1936, sec. 7, par. 13, pp. 7-23 to 7-30.

7. Berger, A. L., and Chenowith, Opie:　The Turbo Super-charger.　SAE Jour., vol. XXIX, no. 4, Oct. 1931, pp. 280-95.

Oil out

Oil in
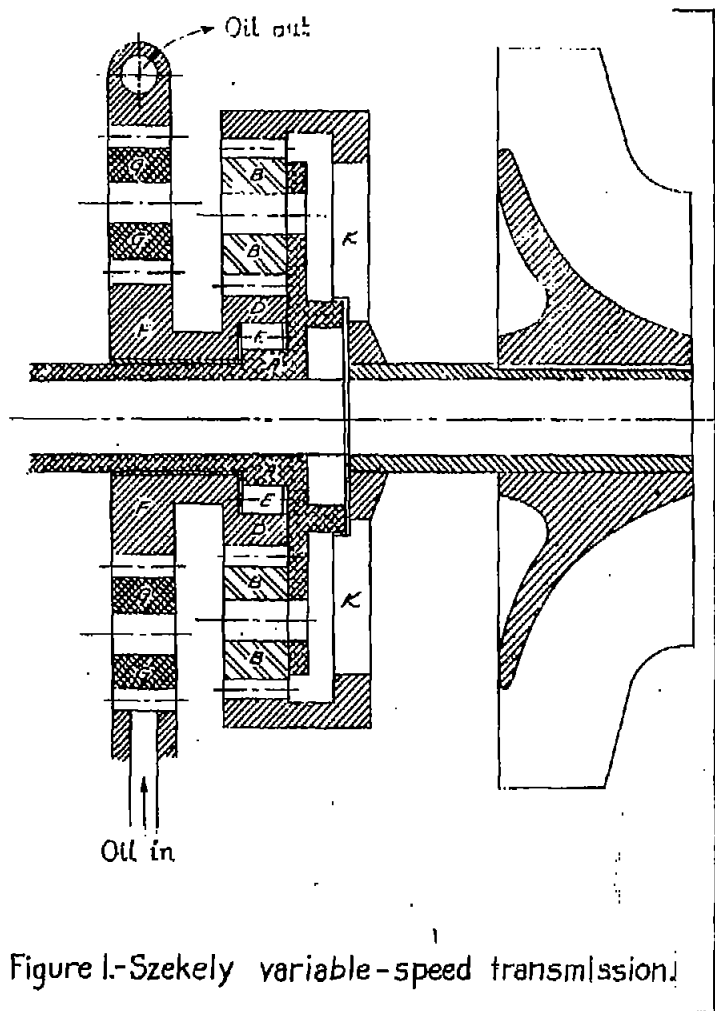
Figure I.-Szekely variable-speed transmission.
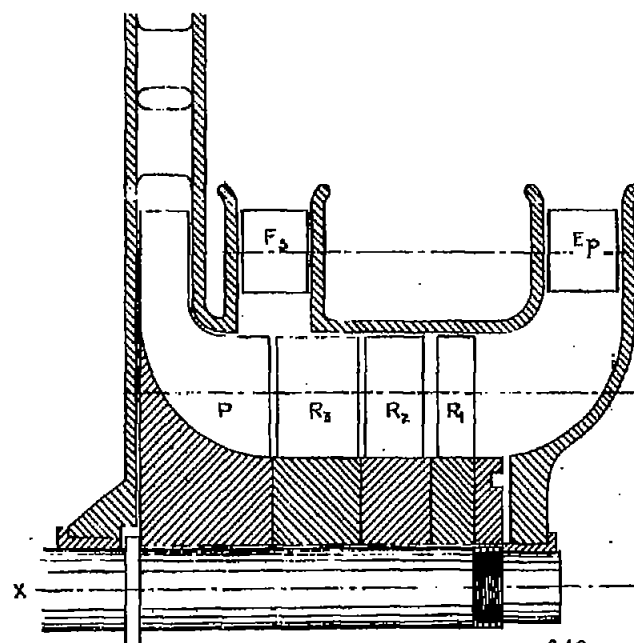
Figure 3.- Szydlowski-Planiol supercharger
(From reference 1.)

NACA Technical Note No. 795

Figs. 1,3
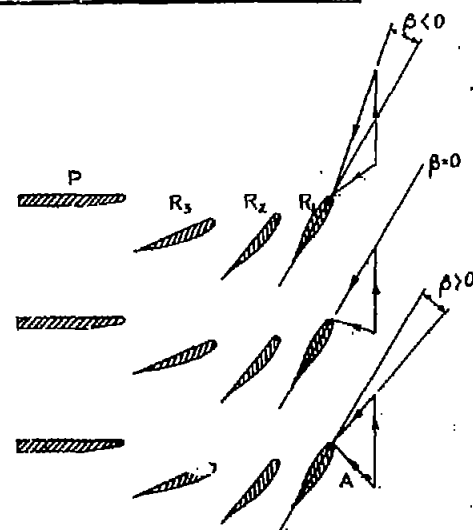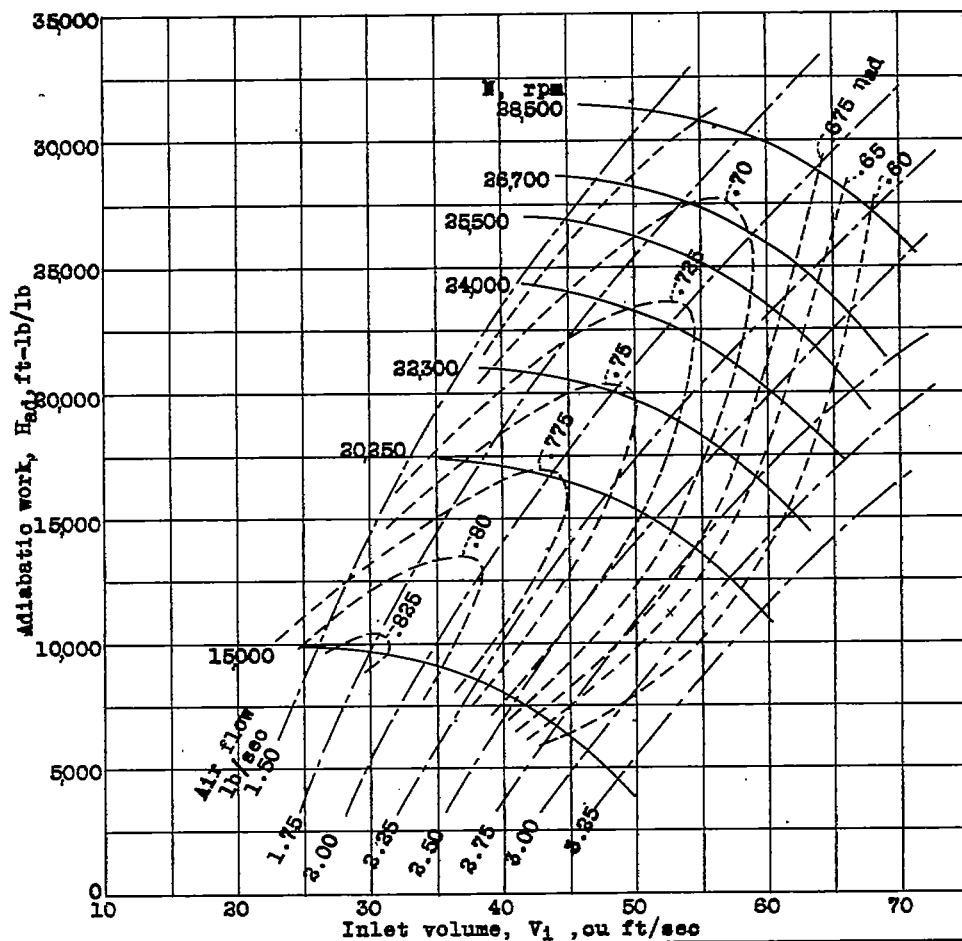
Figure 2.-
characteristics
of DVL super-
charger.
(From refer-
ence 2.)
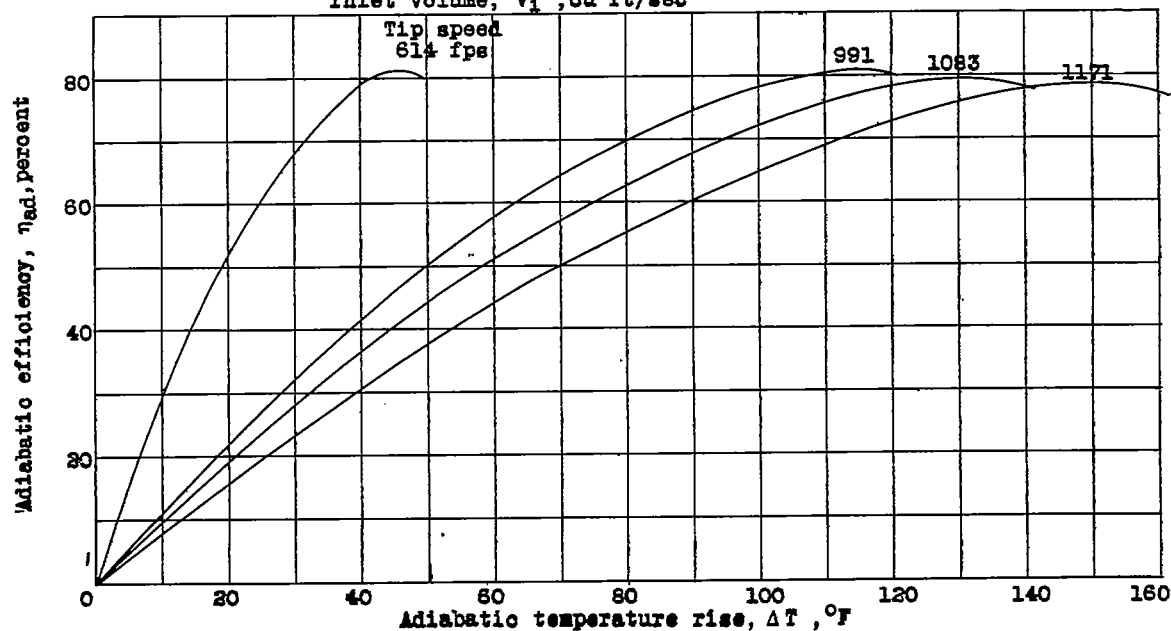
Figure 4.- Characteristics of Szydlowski-Planiol supercharger.
(From reference 1.)
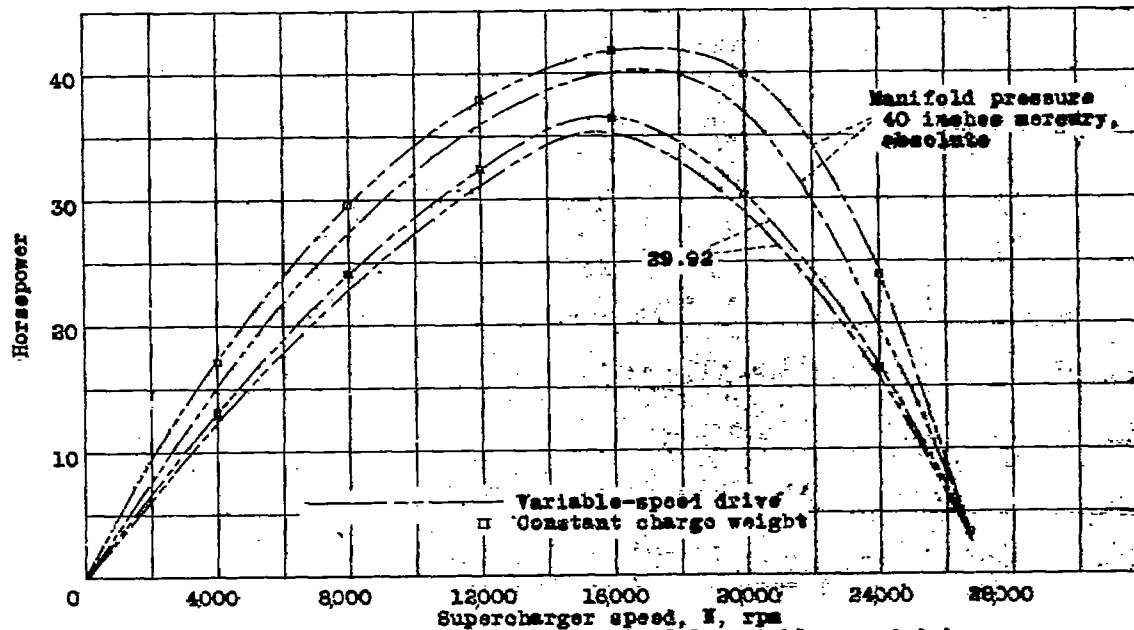
Figure 5.- Transmission loss in DVL variable-speed drive.
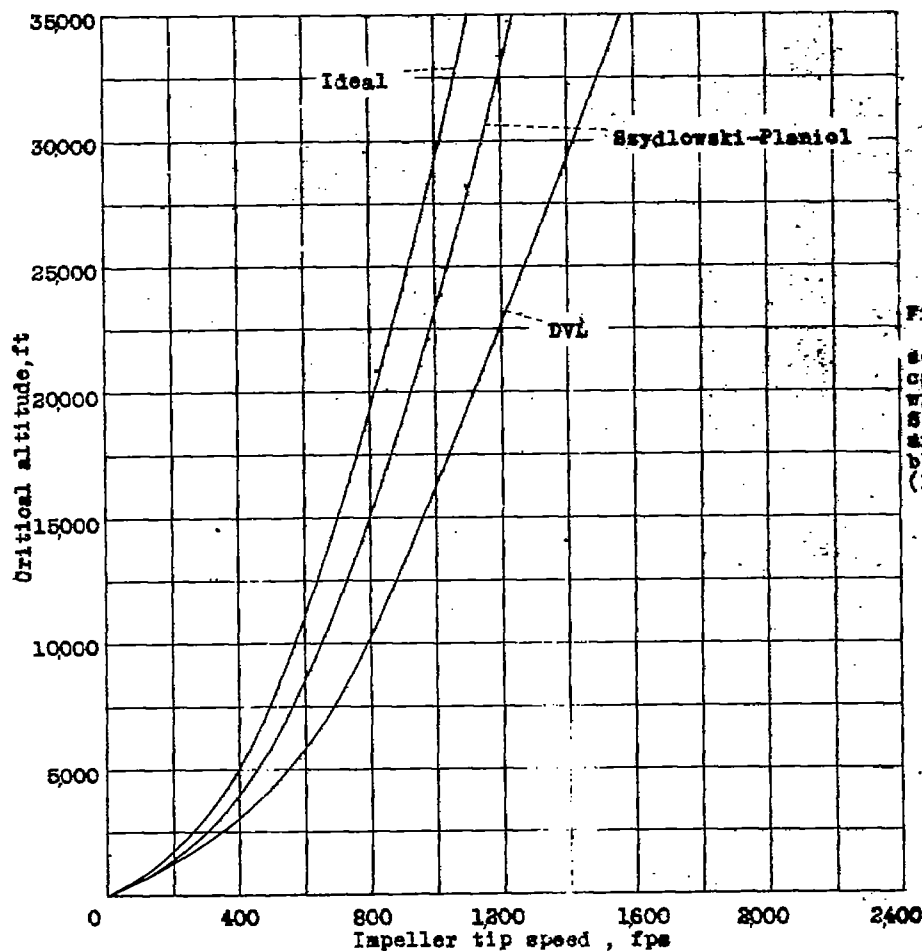
Figure 6.- Altitudes to which sea-level pressure can be maintained with the DVL, the Szydlowski-Planiol, and the ideal radial-blade superchargers. (From reference 1).
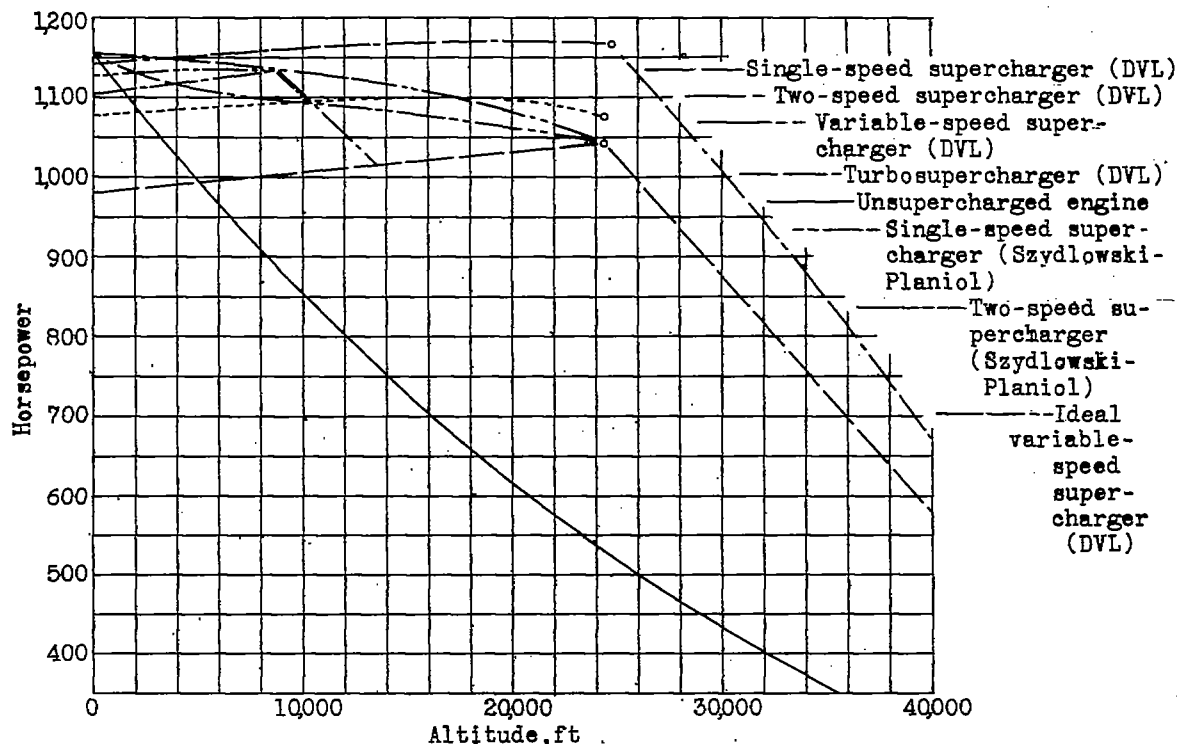
Figure 8.- Variation of propeller power with altitude,constant charge weight.
Manifold pressure below critical altitude,29.92 inches of mercury.
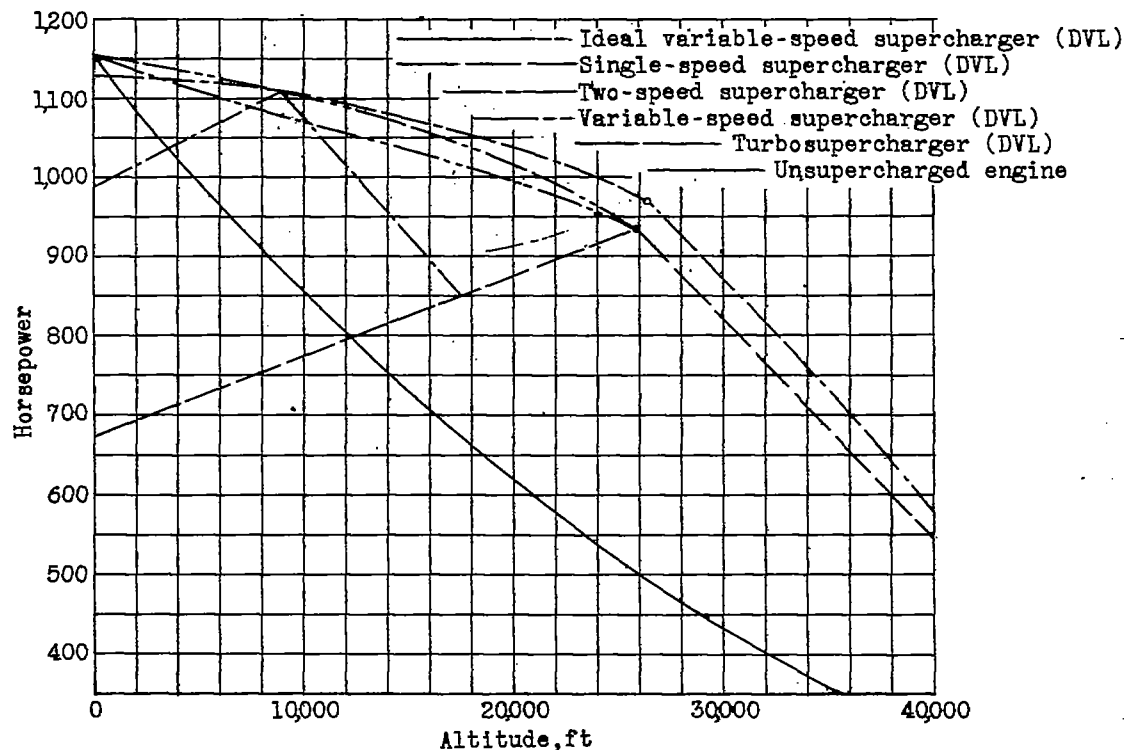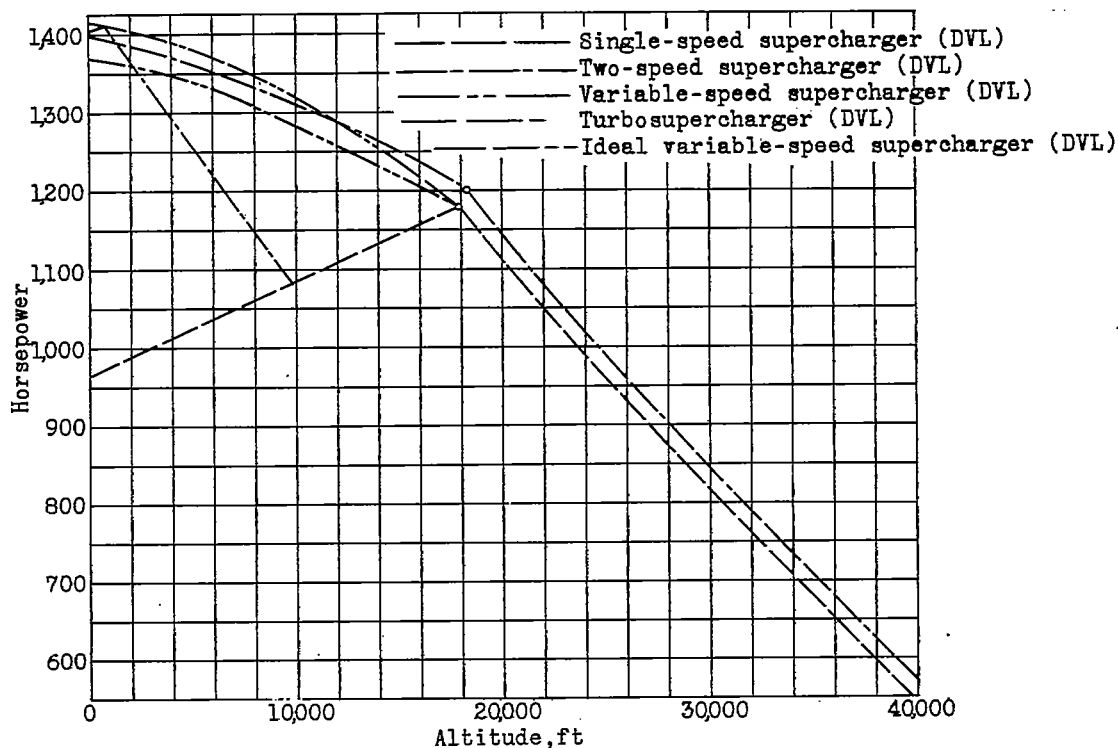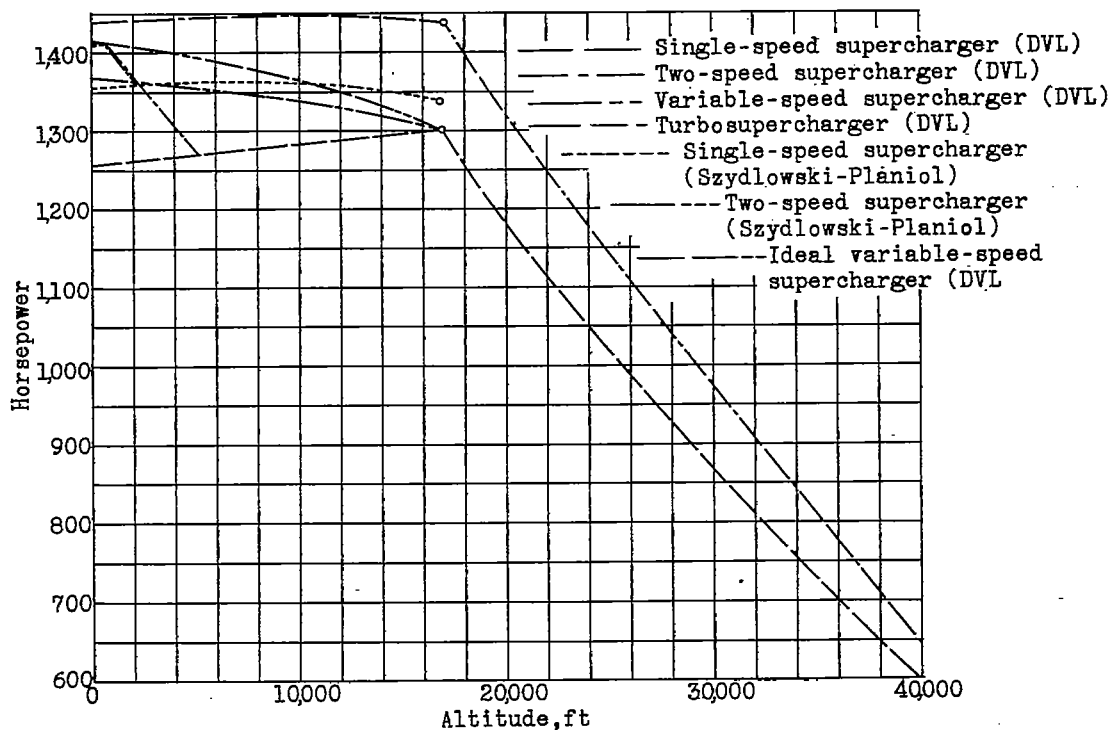

Figure 7.- Variation of propeller with altitude,no intercooling.Manifold pressure below critical altitude,29.92 inches of mercury.
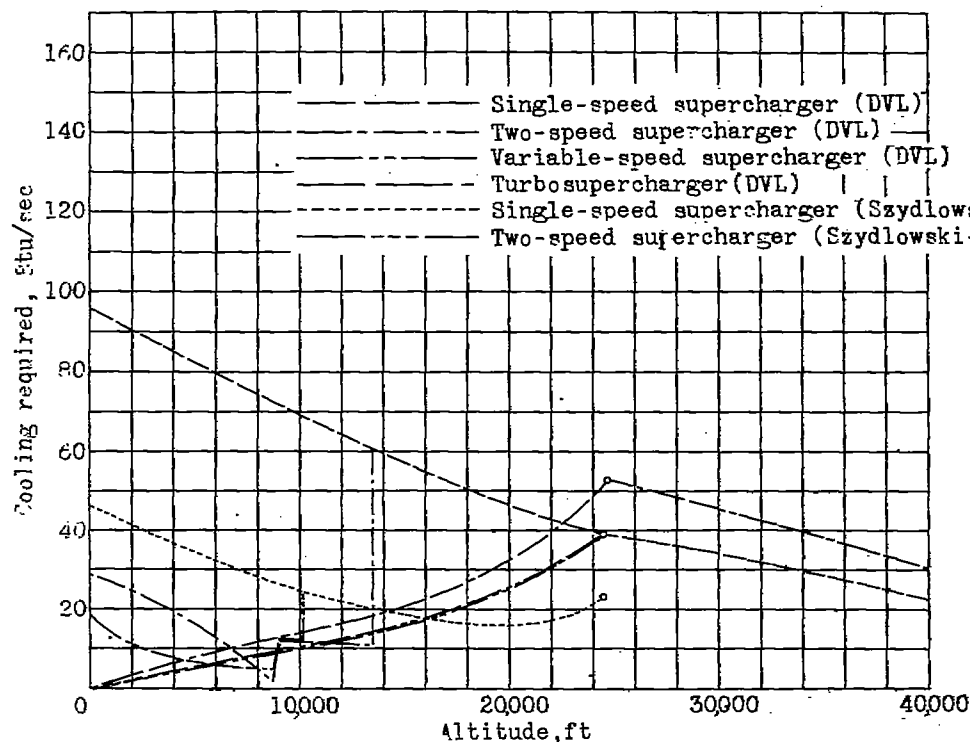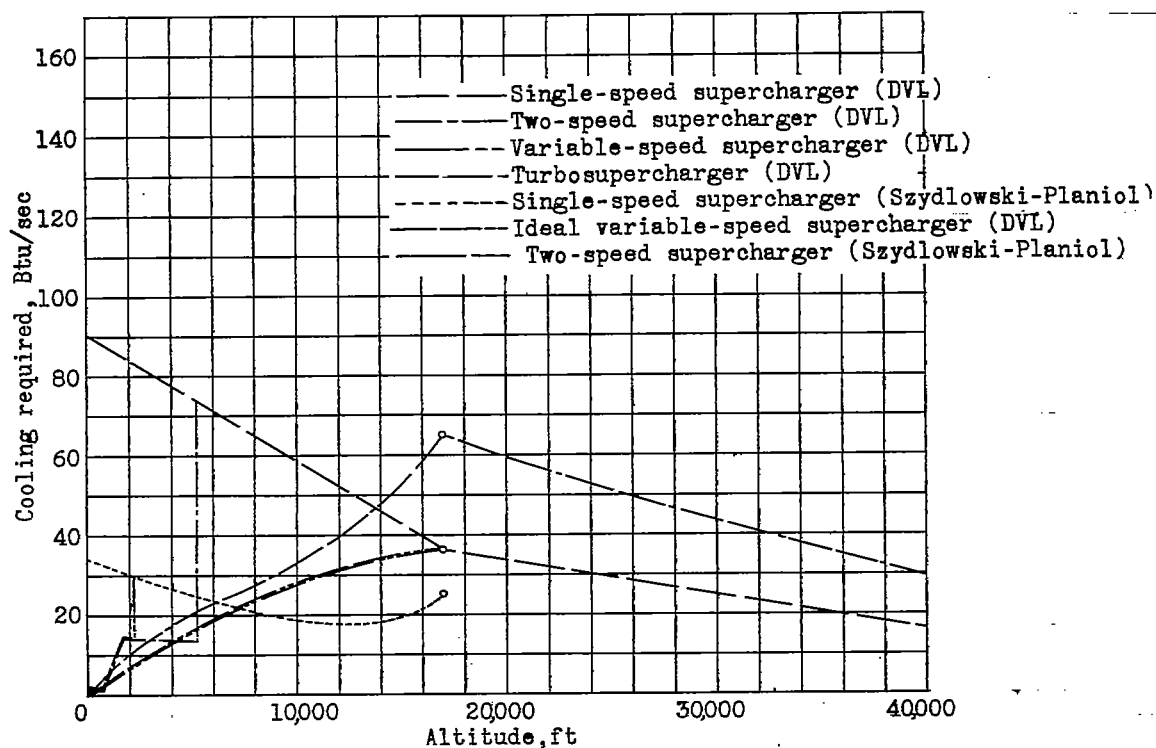
Figure 9.- Amount of intercooling required for various superchargers. Manifold pressure below critical altitude, 29.92 inches of mercury.
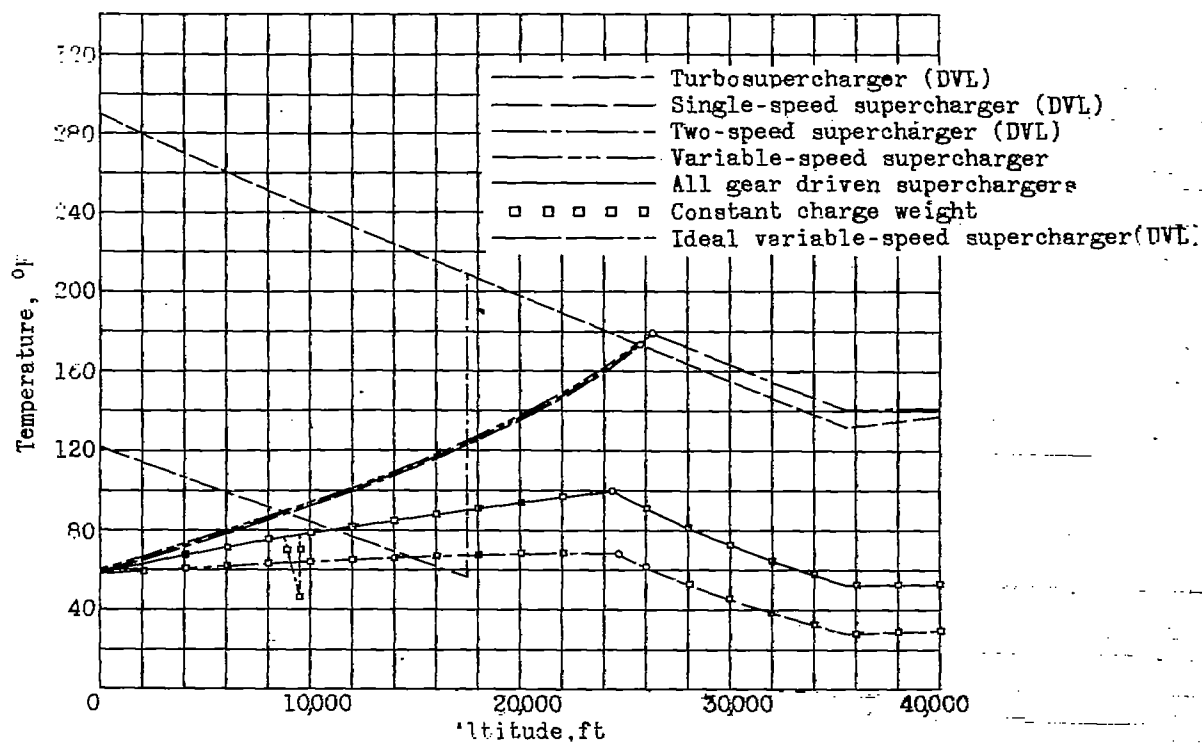
Figure 10.- Manifold temperature for various superchargers. Manifold pressure below critical altitude, 29.92 inches of mercury.
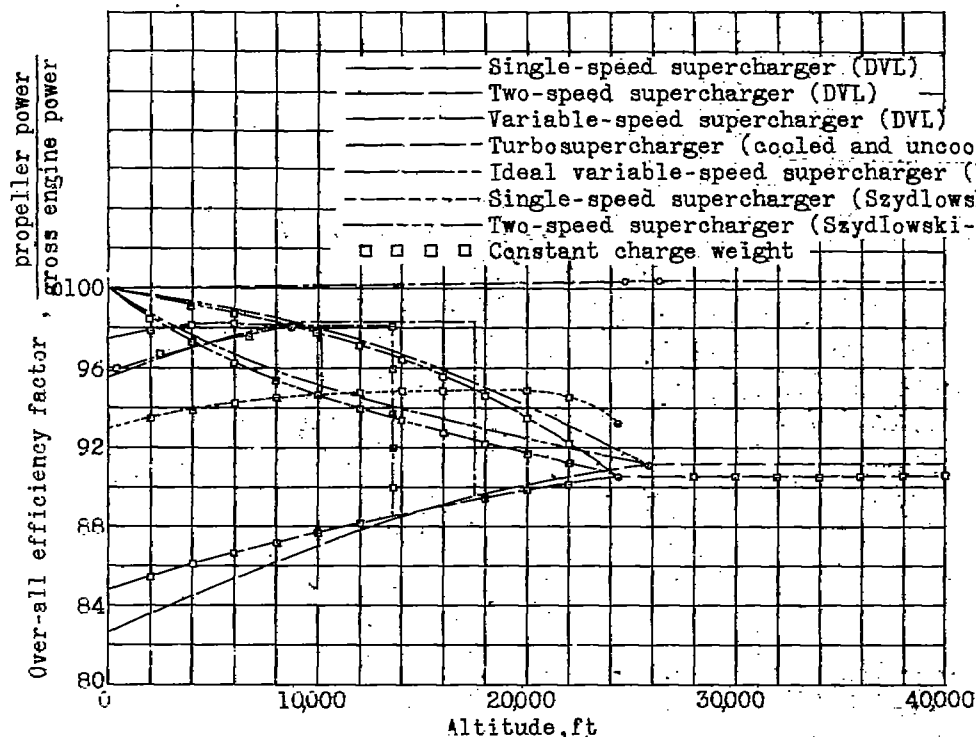
Figure 11.- Over-all efficiency factor for various superchargers.Manifold pressure below critical altitude,29.92 inches of mercury.
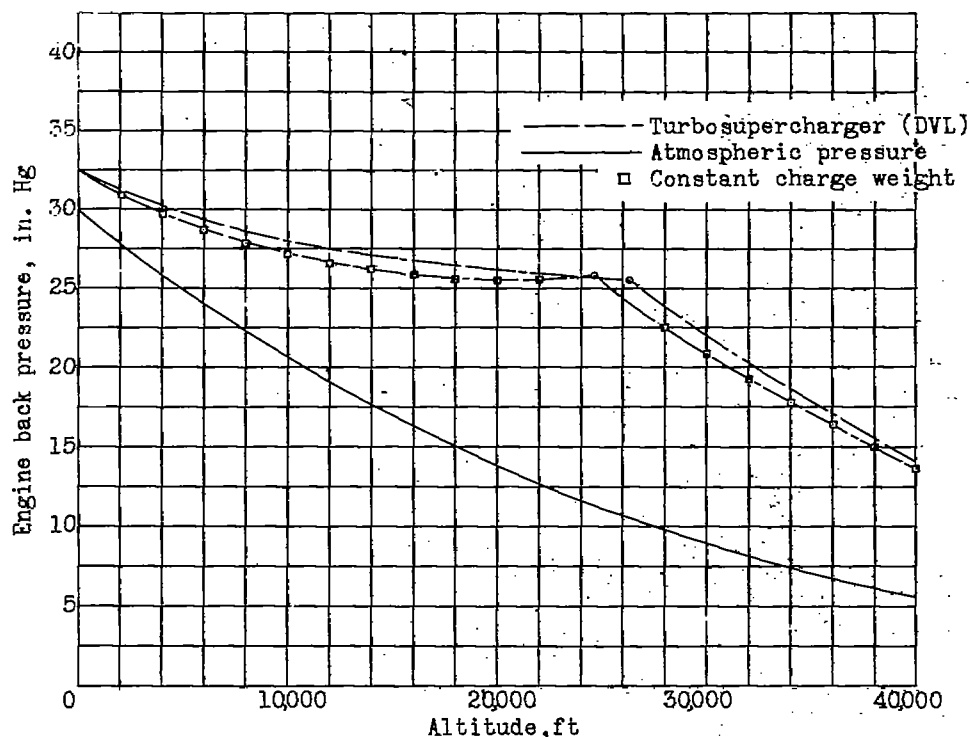
Figure 12.- Engine back pressure for turbosupercharger. Manifold pressure below critical altitude, 29.92 inches of mercury.

Figure 13.- Variation of propeller power with altitude,no intercooling.Mani-
fold pressure below critical altitude,40 inches of mercury.

Figure 14.- Variation of propeller power with altitude,constant charge weight.
Manifold pressure below critical altitude,40 inches of mercury.

Figure 15.- Amount of intercooling required for various superchargers.Manifold pressure below critical altitude,40 inches of mercury.
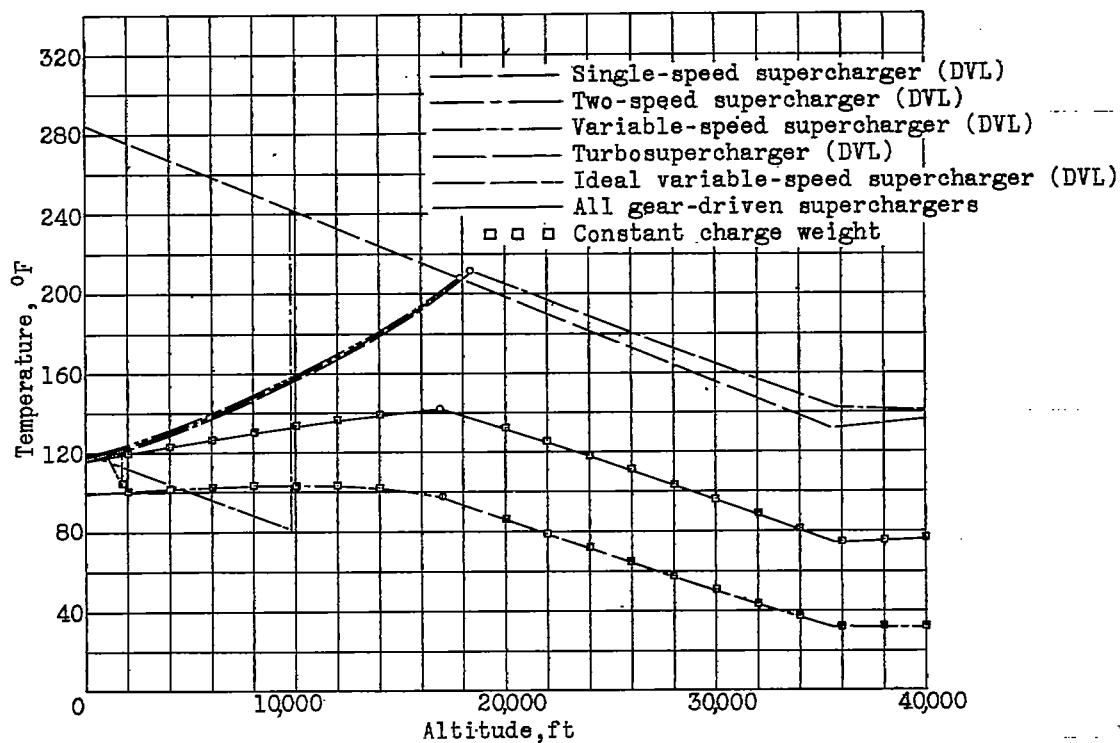

Figure 16.- Manifold temperature for various superchargers. Manifold pressure below critical altitude,40 inches of mercury.
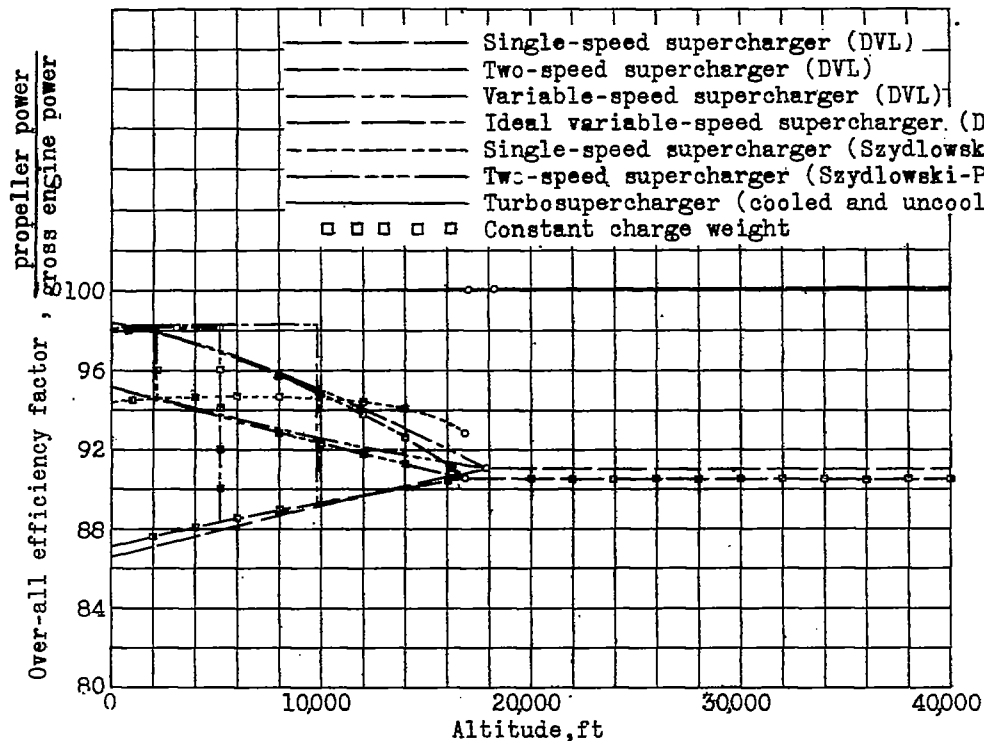
Figure 17.- Over-all efficiency factor for various superchargers. Manifold pressure below critical altitude, 40 inches of mercury.
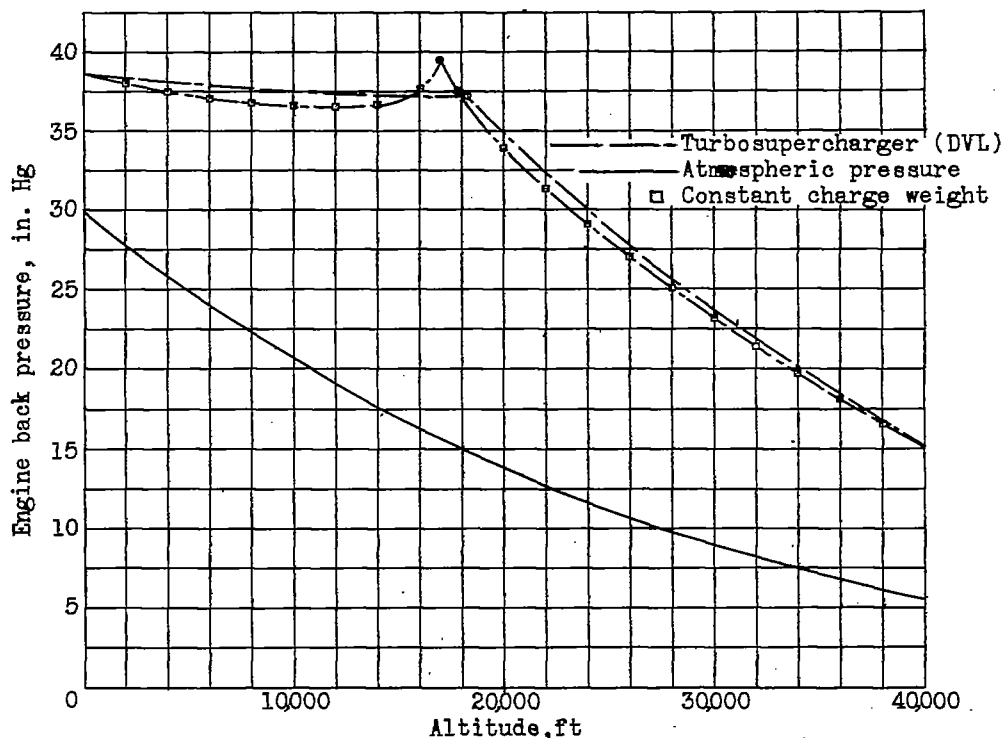

Figure 18.- Engine back pressure for turbosupercharger. Manifold pressure below critical altitude, 40 inches of mercury.